BESCHWERDEKAMMERN DES EUROPÄISCHEN PATENTAMTS

BOARDS OF APPEAL OF THE EUROPEAN PATENT OFFICE

CHAMBRES DE RECOURS DE L'OFFICE EUROPEEN DES BREVETS

Internal distribution code:
(A) [ ] Publication in OJ
(B) [ ] To Chairmen and Members
(C) [ ] To Chairmen
(D) [X] No distribution

Datasheet for the decision of 22 October 2007

Case Number: T 1303/05 - 3.4.02

Application Number: 02009960.2

Publication Number: 1296177

IPC: G02F 1/313

Language of the proceedings: EN

Title of invention:
Photonic crystal waveguide interferometric switch and modulator

Applicant:
Agilent Technologies, Inc.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
-

Decisions cited:
-

Catchword:
-

Europäisches Patentamt | European Patent Office | Office européen des brevets

Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 1303/05 **-** 3.4.02

D E C I S I O N
of the Technical Board of Appeal 3.4.02
of 22 October 2007

Appellant: Agilent Technologies, Inc.
- a Delaware Corporation -
5301 Stevens Creek Boulevard
Santa clara
CA 95051 (US)

Representative: Dilg, Haeusler, Schindelmann
Patentanwaltsgesellschaft mbH
Nußbaumstrasse 6
DE-80336 München (DE)

Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 10 June 2005 refusing European application No. 02009960.2 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: A. Klein
Members: F. Maaswinkel
C. Rennie-Smith

Summary of Facts and Submissions

I. The appellant lodged an appeal, received on 30 June 2005, against the decision of the examining division, dispatched on 10 June 2005, refusing the European patent application 02009960.2. The fee for the appeal was paid on 30 June 2005 and the statement setting out the grounds of appeal was received on 26 September 2005.

The examining division objected that the set of claims then on file was not allowable because the subject-matter of claims 1 to 12 did not involve an inventive step (Articles 52(1) and 56 EPC) having regard to the disclosures in the following documents:

D3: Optical and Quantum Electronics, vol. 32, pages 947 - 961 (2000); R. Stoffer et al.: "Numerical Studies of 2D photonic crystals: Waveguides, coupling between waveguides and filters";

D4: US-A-5 903 010.

In the examining proceedings reference was also made to the following documents:

D1: US-A-6 101 300

D2: WO-A-98/53350

D5: J. D. Joannopoulos et al.: "Photonic crystals", Princeton NJ, USA (1995).

II. With the statement containing the grounds of appeal the appellants filed an amended set of claims to be considered by the board and filed an auxiliary request for oral proceedings. In two telephone conversations with the appellant the rapporteur pointed to remaining deficiencies in the application documents. With a letter dated and received 6 September 2007 the appellant filed a revised request supported by a new set of claims and revised description pages.

III. The documents comprising the request include:

Claims: 1 to 13, as received with the letter of 6 September 2007;

Description: pages 2 to 4, 4a and 5 to 15 as received with the letter of 6 September 2007;

Drawings: sheets 1/4 to 4/4 as originally filed.

IV. The wording of independent claim 1 reads as follows:

"A photonic crystal interferometer apparatus comprising:

a photonic crystal (31);

a waveguide (20) in said photonic crystal (31), said waveguide (20) comprising at least one input portion (32) and at least two output portions (33, 34), said waveguide (20) capable of transmitting light within a bandgap of said photonic crystal (31); and

a resonant member (37) connected to at least one of said at least two output portions (33, 34);

wherein the waveguide comprises an interference channel (35) capable of transmitting light and

connecting said at least two output portions (33, 34);

wherein said apparatus comprises a tuning member (22) connected to said resonant member (37) for controlling a resonant frequency of said resonant member (37) to control a property of light in said at least one of said at least two output portions (33, 34) to control interference of light in said waveguide (20)".

The wording of independent claim 11 reads as follows:

"Use of a photonic crystal interferometer apparatus according to one of the preceding claims as an interferometric switch".

The wording of independent claim 13 reads as follows:

"A method for operating a photonic crystal interferometer apparatus according to one of claims 1 to 10, comprising the step of

controlling the phase of light in the one of two output portions (33 or 34) by the resonant member (37) connected to one of said two output portions (33, 34) to create a constructive interference in one of said two output portions (33 or 34) such that light will propagate through said one of said two output portions (33 or 34), and a destructive interference in the other of said two output portions (33 or 34), such that light will be prohibited from propagating through said other of said two output portions (33 or 34), by changing the resonant frequency of said resonant member (37) to change the phase of light in the one of said two output portions (33 or 34) to switch the propagation of light from one of said two output portions (33 or 34) to the

other of said two output portions (33 or 34) by tuning a tuning member (22) connected to said resonant member (37)".

Claims 2 to 10 and 12 are dependent claims.

V. The appellant's arguments may be summarised as follows:

Independent claim 1 basically corresponds to a combination of claims 1 and 7 as originally filed. Claim 2 is as original claim 2. Claims 3 to 13 correspond to claims 2 to 12 as previously on file, against which the examining division had not raised an objection under Article 123(2) EPC. The independent claims have been re-cast in the one-part form, because the inventive concept is based on the coupling and interaction of the individual optoelectronic components and their functions, which can be better expressed using the one-part form. Thus it is believed that the set of claims comply with the formal requirements of the Convention.

The subject matter of claims 1, 11 and 13 is new, since none of the cited documents Dl to D5 discloses a combination of the respective features of these claims. In particular, compared to claim 1, Dl does not disclose a photonic crystal interferometer apparatus but a high efficiency channel drop filter. Dl also does not disclose an interference channel capable of transmitting light nor a tuning member connected to a resonant member for controlling a resonant frequency of the resonant member to control a property of light in at least one of at least two output portions of a waveguide *to control interference of light in the*

waveguide. Document D2 does not disclose a waveguide *in* a photonic crystal, but a waveguide shaped photonic crystal structure (see claim 1 and Figures 2, 3, *5* and 6 of D2) including defects. In one embodiment D2 discloses a Mach-Zehnder interferometer including optical components formed by photonic crystals (page 7, 1ines 2 to 4). D2 does not disclose an interference channel, but the interference is effected at the output 54. It also does not disclose a resonant member and a tuning member connected to the resonant member for controlling a resonant frequency of the resonant member, but a phase shifter 45. Document D3 does not relate to a photonic crystal interferometer apparatus but to wavelength filters (chapter 5 of D3). Accordingly, D3 also does not disclose a structure including a waveguide comprising *at least one input portion, at least two output portions and an interference channel capable of transmitting light and connecting the at least two output portions.* Furthermore, D3 does not disclose *a tuning member connected to a resonant member for controlling a resonant frequency of the resonant member*. Document D4 discloses an *electron* quantum wire switch. Accordingly, D4 does not disclose a waveguide which is capable of transmitting *light within a bandgap of the photonic crystal* or a tuning member connected to a resonant member to *control interference of light* in the waveguide. The textbook D5 relates to general considerations on two-dimensional photonic crystals. It does not disclose any specific devices or applications or a photonic crystal interferometer apparatus or a corresponding method of controlling. Therefore, the present invention as defined in claim 1 is new. For the same reasons the use of this interferometer as defined in claim 11 and the method as defined in claim 13 for

operating this device are new, since they include corresponding method steps.

The present invention is based on an inventive step, since it is not rendered obvious by any of the documents Dl to D5 or by a combination thereof for the following reasons. In the opinion of the appellant, the closest prior art is reference Dl, since it is the reference which discloses the greatest number of features in common with the present invention. Moreover, the present invention could have been realized most easily on the basis of Dl. This document discloses a photonic crystal including a waveguide comprising at least one input portion, at least two output portions and a resonant member connected to at least one of said at least two output portions. This device does not comprise an interference channel capable of transmitting light and connecting the at least two output portions or a tuning member connected to the resonant member for controlling a resonant frequency of the resonant member to control a property of light in said at least one of said at least two output portions to control interference of light of light in the waveguide. Furthermore, Dl does not disclose a photonic crystal interferometer apparatus in general. Thus Dl does not permit switching operations in a broad frequency range. Compared to Dl, it is the objective technical problem of the present invention to provide a photonic crystal interferometer apparatus and method in which the transmission characteristic does not strongly depend on the frequency. According to the present invention this object is achieved by providing an interference channel which is capable of transmitting light and connects the at least two output portions of

the waveguide and by a tuning member connected to a resonant member for controlling a resonant frequency of the resonant member to control a property of light in the at least one of said at least two output portions to control interference of light in the waveguide and by a corresponding method of controlling. This solution is not rendered obvious by any of the cited references D2 to D5 in combination with Dl. Documents D2 and D3 do not disclose or give any hints of any of the features not known from Dl and, in particular, do not disclose an interference channel which is capable of transmitting light and connects the at least two output portions. Also, none of these documents discloses a tuning member connected to a resonant member for controlling a resonant frequency of the resonant member to control a property of light in the at least one of said two output portions to control interference of light in the waveguide or a method to control the phase of light. D5 relates to theoretical considerations of similarities between quantum mechanics and physics for optical waves in a photonic crystal. It does not disclose any of the features not known from Dl. Document D4 relates to a quantum wire switch. Although a quantum wire switch includes properties which can be described by physical laws which are also applicable to purely optical phenomena, D4 would not have been considered by the person skilled in the art for solving the objective technical problem due to the fact that the device disclosed in D4 cannot be used with optical waves, since it includes a quantum wire structure, and the device has to be operated at cryogenic temperatures. Moreover, D4 clearly indicates that the quantum wire device is only operational for relatively mono-energetic carriers and thus, at single wavelength. Thus

the device according to D4 includes the same shortcoming as D1, which the present invention overcomes. Also, the electron stub tuner disclosed in D4 is not usable in a photonic crystal device as defined in claim 1, since its structure is inherently connected to the physics of electrons. Thus even a combination of the teachings of Dl and D4 does not result in a device as defined in claim 1 or its use as defined in claim 11 or a method as defined in claim 13. Therefore, the present invention is based on an inventive step.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments*

The board is satisfied that the amendments in the claims find support in the respective claims as originally filed as indicated by the appellant. Also the acknowledgement of the prior art is found to be admissible under Article 123(2) EPC.

3. *Patentability*

3.1 Novelty - Claim 1

3.1.1 In the decision under appeal there was no objection of lack of novelty. Indeed the board concurs with the appellant that an apparatus as defined in claim 1 is not anticipated by any of the available prior art documents. In particular none of the documents D1, D3,

D4 and D5 relate to a photonic crystal interferometer. Document D2 discloses in Figure 6 a Mach-Zehnder interferometer comprised of elements (waveguides, filters, mirrors and beam-splitters) made out of photonic crystals. This interferometer comprises neither a resonant member nor a tuning member as defined in claim 1. Furthermore, the two output portions (intrinsic to this type of interferometer) at the combining beam-splitter 51 are not connected by an interference channel as defined in this claim. Therefore the subject-matter of this claim is new (Articles 52(1) and 54 EPC).

3.1.2 Claims 11 and 13

These claims define respectively the use of and a method for operating a photonic crystal apparatus according to claim 1 and appended apparatus claims. The subject-matter of claims 11 and 13 is therefore also new.

3.2 Inventive step

3.2.1 In the Grounds for the appealed decision document D3 had been considered as disclosing the closest prior art (point 1.1 of the Official Communication of 14 March 2005, to which reference was made in the Grounds for the decision). However, in point 1.2 of this Communication it was observed that the device according to D3 differed in several ways from the subject-matter of claim 1. Firstly, it was not an interferometer. In addition, it was noted that the D3 device did not comprise a second output portion nor an interference channel connecting the first and second output portions.

Finally, D3 did not show a tuning member for controlling the resonance frequency of the resonant member.

3.2.2 As explained in the Guidelines for Examination, see Part C, Chapter IV 9.8.1, the determination of the "closest prior art" is that combination of features in one single reference document which constitutes the most promising starting point for an obvious development leading to the claimed invention. It should correspond to a similar use or have the same purpose or effect as in the claimed invention and require the minimum of structural and functional modifications.

3.2.3 Considering this, it appears to the board that document D3 does not constitute the closest prior art, because this document relates to photonic waveguides and filters which may be tunable by including a cavity in a side-branch of the waveguide. It does, however, not relate to an interferometer nor to a switch and, as can be concluded from the further differences between the device of D3 and the subject-matter of claim 1 assessed by the examining division and summarised in point 3.2.1 supra, it would require a rather substantial modification, if not a complete redesign, of the waveguides and filters disclosed in D3 to arrive at the claimed subject-matter. For this reason document D3 is not considered an appropriate starting point for a correct problem and solution approach.

3.2.4 The board has reservations about the position of the appellant that document D1 should be seen as the closest prior art, because, as with D3, this document does not relate to photonic crystal interferometer

apparatus but to a switchable channel drop filter. Rather D2 appears to be an appropriate document disclosing the closest prior art, since it shows in Figure 6 a (Mach-Zehnder) interferometer of which the individual components are made up of photonic crystal elements (D2, page 7, lines 2 to 4). Furthermore the aim of this interferometer is the measurement of the propagation time or time delay within a measurement object 41 which is tantamount to the phase shift in the lower interferometer branch 53. This is measured by controlling the phase shift of the adjustable phase shifter 45 comprising nonlinear optical material of which the dielectric constant can be controlled by varying the applied voltage (page 7, 2nd paragraph). Therefore the general purpose or effect of this device is comparable to the interferometer in claim 1, since by varying the phase shift a property of light in one of the arms (the upper arm) is controlled.

3.2.5 The interferometer defined in claim 1 differs from the device in D2, Figure 6, firstly, in its optical design based on a dissimilar type of interferometer involving a different kind of interference: whereas the two output portions or arms (33, 34) of the interferometer of claim 1, e.g. shown in Figure 2, are connected by an interference channel 35, which causes interference to occur within the interferometer, in a Mach-Zehnder interferometer such as shown in Figure 6 of D2 interference occurs in the orthogonal output portions after the beam combiner 51 between the respective beams of each of these output portions. Furthermore the devices differ in that, in the interferometer defined in claim 1, one of the output portions comprises a resonant member and a controllable tuning member

connected to the resonant member, whereas the interferometer in Figure 6 of D2 contains a controllable phase-shifting member.

3.2.6 These differences over the prior art device allow operation of the interferometer of claim 1 as an optical switch, see page 2, lines 3 to 5 and page 10, lines 12 to 18 of the application as originally filed.

3.2.7 The prior art documents alone or taken in combination do not hint at the solution defined in claim 1. It is true that document D1 discloses a photonic crystal comprising waveguides and a resonant cavity having tunable absorbing characteristics (see column 20, lines 9 to 20), allowing one to switch at a particular frequency the output signal between different waveguides. It is, however, not conceivable, how that device, for instance shown in Figure 3 of D1, could be combined with the Mach-Zehnder interferometer of document D2, and, in any case, even a hypothetical insertion into that interferometer, for instance by replacing the phase shifting member 45 by a resonant cavity connected to the upper waveguide, would still not result in the subject-matter of claim 1, because, as set out in point 3.2.5, a Mach-Zehnder interferometer uses a quite different principle of interference, the interference only occurring after recombination of the two respective beams after the beam-splitter. In contrast, the optical arrangement defined in claim 1 allows the occurrence of interference within the interferometer, for instance at locations 45 and 46 in the one-dimensional model of Figure 3, discussed on pages 11 and 12 of the original patent application.

3.2.8 Conversely, as proposed by the appellant, document D1 could be considered as the closest prior art, because, although relating to a channel drop filter, it has also switching applications and therefore in a general sense has the same purpose as the interferometer of claim 1. A major difference between the apparatus defined in claim 1 and the device of D1 is that the former has a waveguide comprising an input portion and two output portions which, moreover, are connected by an interference channel, whereas the device of D1 comprises two separate waveguides, only coupled via a resonant member. These combined technical features of claim 1 define the particular photonic crystal interferometer structure showing the interference phenomena addressed at pages 10 and 11 of the patent application, which is not suggested in the prior art documents.

3.2.9 In the decision under appeal, after starting from document D3, disclosing numerical studies of photonic crystals, the main line of argument had been based on the disclosure in document D4. This document relates to a quantum wire switch, based on quantum interference and disclosing a similar topological structure as the photonic crystal interferometer of the present patent application. By reference to textbook D5 it was reasoned that the mathematical treatment of wave interference effects for light waves in photonic crystals by the theory of electromagnetism and for electron waves in crystals by quantum mechanics was closely analogous, so that concepts for electron quantum interference devices might in many cases be

transferred to photonic crystal devices in a straightforward way.

3.2.10 Without going into the merits of the degree of analogy or similarity between a particular quantum wire device and a photonic crystal device it appears that the conclusion of lack of inventive step drawn by the examining division, based on a combination of documents D3 and D4 relying on textbook D5, is based on an incorrect problem and solution approach: firstly, as discussed before, document D3 is not a proper closest prior art document for the problem and solution approach. Furthermore, as had been pointed out by the applicant during the examining proceedings in its reply of 25 May 2004, there are major and fundamental differences between the quantum wire switch of D4 and the device according to the invention. For instance, the device of D4 relates to switching of relatively mono-energetic electrons, it needs to operate at cryogenic temperatures and the stub tuner used in that device is quite different from the resonant member in the device according to the invention.

3.3 In conclusion the board finds that neither the teaching of document D2, nor the disclosure in D1, taken alone or in combination, leads to the subject-matter of claim 1 in an obvious way. The disclosure in document D3 bears very little in common with the subject-matter of claim 1 and this document therefore does not constitute a proper starting point for a correct problem and solution approach. Finally D4 and D5 are documents from a rather remote technical field which, in the opinion of the board, would not have been considered by the person of average skill, the more

since the other available documents (D1, D2, D3) do not give any pointer to these documents. Therefore the subject-matter of claim 1 involves an inventive step (Articles 52(1) and 56 EPC).

3.4 The further claims

3.4.1 Claims 11 and 13

These claims define respectively the use of and a method for operating a photonic crystal apparatus according to claim 1 and appended apparatus claims. The subject-matter of claims 11 and 13 therefore also involves an inventive step.

3.4.2 The further claims 2 to 10 and claim 12 are dependent claims and are therefore equally allowable.

4. For the above reasons, the board finds that the appellant's request meets the requirements of the EPC and that a patent can be granted on the basis thereof.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to grant a patent on the basis of the following documents:

Claims: 1 to 13, as received with the letter of 6 September 2007;

Description: pages 2 to 4, 4a and 5 to 15 as received with the letter of 6 September 2007;

Drawings: sheets 1/4 to 4/4 as originally filed.

The Registrar: The Chairman:

M. Kiehl A. G. Klein